McGRAW-HILL YEARBOOK OF
Science & Technology

1996

Preface

The *1996 McGraw-Hill Yearbook of Science & Technology* continues a long tradition of presenting outstanding recent achievements in science and engineering. Thus it serves both as an annual review of what has occurred and as a supplement to the *McGraw-Hill Encyclopedia of Science & Technology*, updating the basic information in the seventh edition (1992) of the Encyclopedia. It also provides a preview of advances that are in the process of unfolding.

The Yearbook reports on topics that were judged by the consulting editors and the editorial staff as being among the most significant recent developments. Each article is written by one or more authors who are specialists on the subject being discussed.

The *McGraw-Hill Yearbook of Science & Technology* continues to provide librarians, students, teachers, the scientific community, and the general public with information needed to keep pace with scientific and technological progress throughout our rapidly changing world.

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EDITOR IN CHIEF

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Library of Congress Cataloging in Publication data

McGraw-Hill yearbook of science and technology.
1962- . New York, McGraw-Hill Book Co.

v. illus. 26 cm.
Vols. for 1962- compiled by the staff of the McGraw-Hill encyclopedia of science and technology.
1. Science—Yearbooks. 2. Technology—Yearbooks. 1. McGraw-Hill encyclopedia of science and technology.
Q1.M13 505.8 62-12028

Printed on acid-free paper.

ISBN 0-07-051772-X
ISSN 0076-2016

late with the same female. Postcopulatory defense of the female by the mating male from other males has not been observed.

Insemination and sexual strategies. The term mating plug does not apply to open thelycum species of penaeoids since deposited spermatophores are attached to the external surface of the female and are fully exposed. Indeed, in species such as *P. setiferus* the spermatophores are easily dislodged from the thelycum. In contrast, in a closed thelycum species such as *P. aztecus*, the appendages of the spermatophores undergo a reaction with seawater, expanding and covering the aperture to the seminal receptacle, with subsequent hardening to form a seal or plug. In *T. similis*, first the small sperm packets are deposited into the median pocket of the thelycum, followed by the plug substance which apparently forces the sperm into the apertures of the paired, internalized seminal receptacles. The plug substance quickly hardens in the median pocket, sealing off the apertures of the receptacles from contact with the exterior of the female. Mating plugs may serve to stop sperm or spermatophoric materials from leaking back out to the exterior. They may also prevent deterioration of stored sperm by bacteria, fungi, and other microorganisms ubiquitous in the surrounding seawater. In addition, subsequent insemination of the female by another male is rendered impossible.

Penaeoid mating plugs thus function as paternity assurance devices. By ensuring that its sperm is stored and not mixed or replaced with that of other males, the inseminating male guarantees that the eggs of all spawnings by the female during the intermolt period will be fertilized by only its sperm. This arrangement may not be entirely adaptive for the female if the inseminating male does not supply enough sperm to completely fertilize all spawns or if the male is in some way genetically inferior to other possible mates.

In the sicyoniids *Sicyonia dorsalis* and *S. parri*, males do not produce a mating plug. A fluid sperm mass is directly deposited into the internalized seminal receptacles. Unlike penaeoid males, which produce mating plugs, a *Sicyonia* male can inseminate only one of the two receptacles with a single copulation. Furthermore, studies have shown that females may copulate with males without allowing insemination. Multiple copulations with one or more males may function as a courtship device by which females can choose a desirable or superior male. Since several males often crowd around a receptive female, it is quite likely that in nature, a female might choose to be inseminated by two different males (one filling each of the paired receptacles). Multiple male mating partners are possible since there is no mating plug to prevent sperm from being added to and mixing with a partially filled receptacle. Thus, it appears that sicyoniid females have some advantages over males regarding reproduction, the absence of a mating plug allowing them to mate repeatedly, thereby permitting a maximal filling of the receptacles and the possibility of insemination by more than one male. Multiple paternity of a female's spawnings has the advantage of increasing the genetic diversity of the numerous offspring—a benefit in changing, variable environments like the sea.

For background information SEE DECAPODA (CRUSTACEA) in the McGraw-Hill Encyclopedia of Science & Technology.

Raymond T. Bauer

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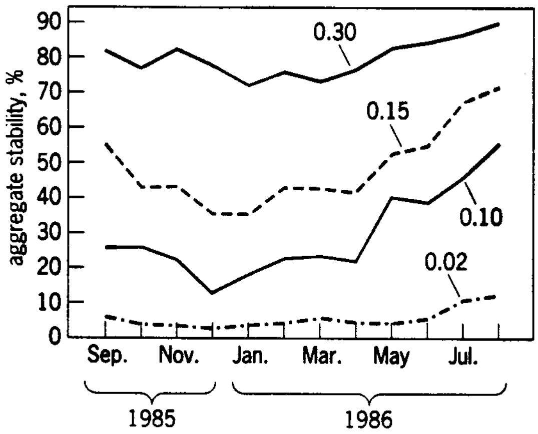
Soil

A soil's ability to resist structural deterioration is one of its most important physical properties. An aggregate, a unit of soil structure, is a cluster or coherent association of primary particles (sand, silt, or clay) that has been cemented or bound together by organic or inorganic constituents. A quantitative measure of an aggregate's resistance to some applied disruptive force is its aggregate stability. Stability is usually measured by sieving aggregates in water, and is reported as the percent by weight of aggregates that remain clustered after sieving.

Aggregate stability. Aggregate stability affects the rate at which a soil erodes and the rate at which water infiltrates a soil's surface. A soil's susceptibility to erosion by either water or wind decreases as aggregate stability increases. Aggregate stability is also a quantitative measure of soil tilth. Soils with poor structure contain unstable aggregates. Such soils crust easily, compact readily, and may be poorly aerated. Crusting of the soil surface hinders or prevents seedlings from emerging, whereas sealing reduces infiltration and increases surface runoff; both conditions thus result in impaired crop production.

Deeper in the soil profile, unstable aggregates adjacent to existing soil pores can fracture when wetted, releasing primary particles and aggregate fragments that can constrict or obstruct pores. In contrast, soils with many large pores of diameters ≥ 1 mm (0.04 in.) contain relatively large stable aggregates. Large, continuous pores open to the soil surface increase the rate at which both water and air pass through the soil profile. A soil with a wide range of pore sizes is agriculturally productive because stable pores of all sizes are necessary for infiltration, drainage, water retention, root exploration, enhanced biotic activity, and gas exchange. Production practices that stimulate the formation, stabilization, and persistence of larger aggregates in



Aggregate stability as a function of time and presieved water content for a Portneuf silt loam. The values given represent kilograms of water per kilogram of dry soil. *(After M. S. Bullock, W. D. Kemper, and S. D. Nelson, Soil cohesion as affected by freezing, water content, time and tillage, Soil Sci. Soc. Amer. J., 52:770–776, 1988)*

soils result in greater productivity as well as resistance to crusting, erosion, and compaction.

Temporal variation. Aggregates are affected by many factors that cause stability to vary over time. Tillage, climatic processes (rainfall, freezing, and thawing), microbial activity, and crop residue management are all linked to temporal variation in aggregate stability. All must be managed or considered if soils are to support continued production of food and fiber.

Soil scientists have classified soils into different soil series based upon their kind and upon the arrangement of horizons; color, texture, and structure; and chemical and mineralogical properties. The **illustration** shows the annual variation in aggregate stability for one soil, a Portneuf silt loam, classified as a durixerollic calciorthid, from southcentral Idaho. In general, in early spring (April to May), aggregate stability increases rapidly from a winter low value. Through the remainder of the summer, aggregate stability continues to increase, but at a slower rate, to reach a maximum in August. In soils subject to freezing, aggregate stability in general decreases steadily from the fall to midwinter. The stability of Portneuf aggregates also varies within a season and from one year to the next. In short, changes in aggregate stability over time follow both short- and long-term trends, making characterization and prediction difficult.

Because of its correlation with erosion, aggregate stability has potential as a predictor of a soil's susceptibility to erosion. However, poorly characterized short- and long-term variation in the property has hampered attempts to employ it in that capacity. Better prediction of temporal variation in aggregate stability will greatly enhance its value for erosion prediction. Better understanding of the underlying processes affecting aggregate stabilization might lead to improvements of crop production practices or to irrigation techniques that would reduce erosion.

Physical and chemical factors. Many of the physical and chemical factors that cause aggregate stability to vary over time are related to climatic processes such as precipitation, evaporation, and freezing.

Wetting and drying. Wetting and drying affect the water content of an aggregate, which is important because water content is indirectly proportional to the aggregate's stability. Soils that have dried in the field are more stable, probably owing to inorganic bonding agents at particle-to-particle contact points. Drying also gathers and reorients clay particles and clay domains in a more orderly, parallel arrangement at the contact points between sand and silt particles. The water content of an aggregate also dictates the relative volume of air entrapped within the aggregate when it is rapidly wetted. Air trapped within an aggregate is first compressed, then forced to escape through the outer wetted and weakened layers, often breaking the aggregate. The illustration shows the dramatic effect that an aggregate's presieved water content (indirectly proportional to entrapped air volume) has upon its stability. Air entrapment during rapid wetting is obviously a primary cause of aggregate breakdown. Wetting and drying also cause swelling and shrinkage, respectively, thus generating stresses that can either break or form interparticle bonds.

Aggregates are wetted by irrigation, precipitation (rain or snow), or diurnal redistribution of soil water and dew. When aggregates at the soil surface are struck by drops of water, they can be weakened or broken, releasing primary particles or smaller aggregates that may seal the soil surface. A surface seal limits infiltration and can hasten surface ponding of water. When relatively dry aggregates are quickly hydrated, they are subjected to forces exerted by differential swelling, air entrapment, and localized heat of wetting. Aggregates in flowing runoff are subjected to the additional shear forces of the moving water and abrasion along the flow path. These forces develop, in the aggregates, planes of weakness along which they fracture when forces reach critical limits.

Diffusion and chemical precipitation. As aggregates dry, their stabilities often increase due to the diffusion and precipitation of cementing or bonding agents. As a soil dries, slightly soluble bonding agents, such as calcium carbonate, silica, or iron oxides, diffuse through the thin films of water that surround aggregates to the larger pockets of water that remain at the points of contact between primary particles or smaller aggregates. As drying continues, the concentration of the bonding agents in these water pockets increases. Ultimately, they precipitate, cementing the particles to one another. The steady increase in Portneuf aggregate stability from April through August (see illus.) results in part from this diffusion/precipitation process caused by repeated wetting and particularly drying over the summer.

Freezing and thawing. As a soil freezes, temperature differences cause liquid water to develop ice lenses through the unfrozen water films that surround soil particles. As this water flows, it carries some slightly soluble bonding agents to the contact points between soil particles. Once there, they precipitate, strengthening the aggregates. However, if a developing ice lens is near an aggregate, the enlarging lens can compress nearby constrained aggregates, either weakening or strengthening them depending on their water content, solute concentrations, and freezing history. In the portion of the soil profile supplying water to the ice lens, aggregates become drier and bonding agents precipitate at particle contact points. The fact that temperate soils often exhibit greater annual variation in aggregate stability than do tropical soils may, in part, be due to freezing and thawing. In addition, freeze-drying, a process in which ice sublimes from frozen aggregates on or near the soil surface, may affect the stability of aggregates from temperate soils in some areas.

Biological factors. Those factors that can cause variation include root growth, microbial activity, and residue management.

Root growth. Roots, as they elongate, move nearby aggregates and soil particles closer to one another. Contact points among them increase, thus providing more sites for potential stabilization. This process may account for some of the increase in aggregate stability often seen under no-till cultivation or in pastures. As roots and fungal hyphae grow, they quickly bind smaller aggregates into larger ones, which, if stabilized, improve soil structure and tilth.

As plants grow, roots withdraw large amounts of water from the soil to meet the plant's transpiration demand. This extraction of soil water by roots is yet another source of intensive and frequent soil drying. The precipitation process ensues, but in addition the water flowing to the roots concentrates the soluble bonding agents in the soil near the roots.

Microbial activity. Soil microbial activity intensifies in the spring and early summer as the soil warms and drains to field capacity. Microbes decompose plant residues, sloughed root cells, and root mucilage. In the process, they produce extracellular polysaccharides that, along with other organic compounds excreted by living roots, stabilize aggregates.

Residue management. Farmers can maintain high soil organic matter levels and increase aggregate stability by incorporating crop residues into the soil. The properties of the incorporated plant residue determine the extent of its effect on aggregate stability. If plant materials are easily decomposed, microbiological activity quickly produces extracellular polysaccharides that stabilize aggregates. As the growing season progresses, easily decomposable, carbonaceous material from plant residues may become limiting. Microbes then may use polysaccharides and other stabilizing materials as substrate, decreasing aggregate stability as the season continues. More recalcitrant plant residues can indirectly improve aggregate stability, but over a longer period of decomposition.

Cultural factors. The cultural factors responsible for temporal variation include tillage and irrigation.

Tillage. Disturbing soils by tilling them affects their structure according to the amount and kind of disturbance. As a tillage tool passes through a well-aggregated soil, it compresses some aggregates and shears others. These stresses either fracture aggregates or weaken them by creating potential failure planes. Aggregate stability often decreases immediately after tillage or cultivation. Tillage also influences aggregate stability by decreasing soil organic matter. The breaking of clods and mixing of soil by tillage dries the soil and increases its temperature, thus stimulating microbes to oxidize newly exposed organic matter. Tilling a wet soil is particularly damaging to the soil's structure and also increases its bulk density below the tillage depth. *SEE AGRICULTURAL SOIL AND CROP PRACTICES.*

Irrigation. Those aggregates on the soil surface are most likely to be affected by irrigation. Sprinkler irrigation affects aggregates in much the same manner as does natural rainfall. Raindrop or sprinkler-drop impact can disintegrate or weaken aggregates, leading to sealing of the soil surface. Surface irrigation, either furrow or flood, wets dry aggregates relatively quickly by immersing them in the water flowing over the soil surface. The escaping of entrapped air from within the aggregates often fractures them. Improper irrigation management or lack of drainage can also increase salt concentrations at the soil surface. Sodium accumulations disperse soil clays and destroy soil structure.

For background information *SEE AGRICULTURAL SOIL AND CROP PRACTICES; EROSION; IRRIGATION (AGRICULTURE); SOIL; SOIL MICROBIOLOGY* in the McGraw-Hill Encyclopedia of Science & Technology.

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Solar system

The meteorites, the Earth, the Moon and probably all terrestrial planets are depleted in volatile elements (for example, potassium, rubidium, and lead) relative to solar or C1 chondritic abundances. Thus, the material forming the meteorites and planets has most likely been thermally processed at temperatures of about 1200–1400 K (1700–2100°F).